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Seventy-four presents were announced as having been received since the last meeting, including amongst others :

Astronomische Gesellschaft, Catalog, vi. Zone +40° bis +50° (Bonn), presented by the Society ; J. E. Gore, The Worlds of Space, and J. R. Hind, Illustrated London Astronomy, presented by Mr. M. C. Sharp; *Nautical Almanac* for 1898, and ditto, Part I., presented by the Lords Commissioners of the Admiralty; photograph of *Orion*, &c., made with a small camera, presented by Dr. Sheldon ; a series of eight untouched enlargements of portions of the Moon, from a negative by Lœwy and Puiseux, made and presented by Professor L. Weinek.

Preliminary Note on a Modified (Oblique) form of Cassegrain Telescope. By A. A. Common, LL.D., F.R.S.

Reflecting telescopes on the Cassegrain system, but with the convex mirror placed so as not to obstruct the light from the object, and with the mirrors tilted so as to throw the image to one side of the large mirror, appear to have been made in Germany many years ago.

I first learnt this from Dr. Hugo Schroeder in the course of a conversation about the possible forms of the reflecting telescope. This was, I think, before I began the present 5-foot telescope in 1886. He suggested that I should make it on this principle, and I made some experiments with small mirrors, but, as far as I remember, I did not get better definition than the Herschelian form would give. More than one eminent authority on the theoretical side assured me that good definition was not possible on this plan, and I did not then pursue the experiments further. In 1892 I found it so difficult to properly fix a spectroscope to the 5-foot, and to manipulate it from the stage, and the danger of getting up and down from a high stage in the dark becoming rather pronounced, I determined to seek some more convenient form of telescope.

As I had a 5-foot mirror with a hole in the centre, I could use the Cassegrain form, but before doing so I decided to try again the oblique form, as this allowed high altitudes with my form of mounting. From my previous trials, and from what I had heard from others of the possible definition, I was led only to expect perhaps enough for spectroscopic work.

The results of my experiments, however, have been, in my opinion, so thoroughly satisfactory, that I think it right to lay them before the Society.

Having nothing to go upon except the fact mentioned by Dr. Schroeder, that small telescopes on this plan had been made, and not being able to attack the problem from the theoretical side, I had to do so from the experimental or practical side. I began by trying the effect of a convex mirror on the obliquely

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reflected rays from a 20-inch mirror of short focus length (so that the adverse conditions would be intensified), using an illuminated pinhole at the centre of curvature. Experiment showed that at certain angles the astigmatism of the image from the concave mirror could be almost entirely eliminated by the opposite astigmatism of the convex; this was very evident when extreme angles of obliquity were used. This compensating principle, once established, gave great hopes of success.

A mounting was erected to carry a 6-inch or 12-inch concave speculum, with provision for using various convex mirrors, and experiments made to find the combination of curves and angles that would give the best definition on stars. Many experiments were made with more or less success, and a great deal of time was lost through bad weather. Combinations that gave excellent results on the Sun failed to give a perfectly round image of a star. With mirrors smaller than 6 inches a very fine stellar image was obtained on more than one occasion. This trial telescope was given up in favour of an artificial star in the workshop and a parallel beam from a 6-inch achromatic; this allowed the carrying on of the experiments continuously.

Hitherto the angle of reflection from the small mirror had been kept the same as that from the large one, but it was soon found that to get proper definition the angle of the second reflection had to be considerably larger than the first.

The conditions that seemed to answer best, and which gave, as far as could be seen with this arrangement, perfect definition, were, a focal length of the concave mirror of 10, aperture being 1, a radius of curvature for the convex mirror $\frac{3}{4}$ of concave, and distance from concave $\frac{2}{5}$ of focal length; the angle between first central incident and reflected ray being 5° 30′, and between the second 12° 30′.

With these conditions it was decided to try this form of telescope on a large scale, using as much of the 5-foot mirror as the focal length would allow under these conditions (about 32 inches); the flat mounting of the 5-foot was cleared away, an 18-inch tube about 20 feet long was fitted to the main tube, with an eye-end and arrangement for carrying a convex mirror with adjustments. Two 15-inch convex mirrors were made to the proper curvature. With this arrangement the stars were not perfectly round—in fact they all had tails, and in appearance were very like comets with short tails. Definition was fairly good on the Moon, as photographs taken with this telescope which are laid before the Society show. They are almost, if not quite, as good as any I have hitherto obtained.

The defect in the image of a star was considered to be due to the fact that owing to the shape of the square tube of the 5 foot and the want of sufficient play to move the mirror, an eccentric portion had to be used. This difficulty could not be overcome, so it was decided to make a 30-inch mirror of the same focal length and fit it in the cell of the C speculum, which was in

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the workshop. This mirror was made and silvered, and the C speculum taken out of its cell and this mirror put in, eccentrically as regarded the cell, but in the proper position as regarded the position of the convex mirror and the possible place of image. The B mirror was taken out of the telescope and the 30-inch mirror and cell put in its place. This was completed a few days before last Christmas, and the first opportunity taken of examining a star; when it was found that, as far as could be seen on that night, which was not very good, the stars were round, and free from any kind of appendage. Inside and outside the focus the discs were quite circular. Observations since made show that with a power of 1100 the image of the star is not quite round, with lower powers it seems so. This slight defect, I consider, may be due to a slight want of adjustment.

On the Moon the definition was very fine indeed, finer than anything I have yet seen. *Jupiter* was very finely seen in a quite dark field. This was a striking contrast to the usual field with the 5-foot when such a bright object as *Jupiter* was under examination.

The advantages of this form of reflecting telescope are many and important, particularly so in the case of very large telescopes. The greatest gain is, perhaps, in the change of position of the image, so that a low stage near the centre of motion of the telescope and the ground level, will take the place of the high stage with its continuous shifting to suit the height of the end of the telescope and the motion in time.

The increase of focal length is a gain both for visual and spectroscopic work; it may not be so good for nebular photography, but it is quite an open question whether the larger primary image is not at any time worth the greater time in exposure required, and plates are improving so rapidly that this will not be felt. (Using the 5-foot aperture some years ago, I gave quarter of a second exposure to the Moon. In November last I took a picture of the Moon with a convex mirror, giving an equivalent focal length of about 80 feet and an image 8½ inches in diameter. Using only one foot aperture and two seconds exposure, I obtained a picture with ample density.)

The place of the image being near the strongest part of the tube, any kind of apparatus can be rigidly attached and manipulated under the most variable circumstances.

The dark field to which I have alluded is a great advantage on such objects as *Hyperion*, and the absence of the cause of the diffraction lines (the supports of the small mirror of the Newtonian) will tell on photographs of stars.

There is hardly a defect under which the large reflector at present labours that this plan of telescope will not remove, whilst it brings in some distinct gains of its own—as, for instance, the substitution of a convex for a plane mirror, and the great shortening of length of tube for a given focal length. In this latter respect the gain can be very great, an equivalent focal

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length of, say, 200 feet, requiring in the case of the Newtonian a tube nearly this length, can be obtained by a tube of about 66 feet. In no other way could such a large primary image as a focal length of 200 feet would give be obtained, while retaining, say, 1° of the field. The image of the Moon would here be about 22 inches in diameter, with the above relation of curvature of surfaces, but this relation need not necessarily be adhered to, where, for the Sun or Moon, the aperture might be very much less than in the proportion given, as an increase in the curvature of the convex mirror produces a longer equivalent focal length; and as this can be done more easily as the aperture of the concave mirror is reduced, and the first angle made smaller, a much greater equivalent focal length could be obtained; and as I have shown, one foot of aperture is sufficient to give an image of the Moon when the equivalent focal length is 80 feet, a mirror of, say, 2 feet aperture and a slightly longer exposure, mounted on any of the very large refractors in existence, would easily give a much larger primary image—too large, perhaps, to photograph as a whole, but excellent for portions of such an object as the Moon.

The conditions I have given may not be the best to get the finest definition: probably they are not. It is easy to see that where there is a balancing process at work between the two mirrors, the angles of incidence and the place where the image is produced have an importance, as well as the curves of the mirrors. With a parabolic mirror and a spherical convex, the image is as it would be in the Cassegrain form, with these mirrors overcorrected. Whether it would be an advantage to reduce the amount of correction given to the concave mirror, to make it as if the focal length were to be the equivalent focal length; or whether it would be better to obtain this correction, as in the Cassegrain, by making the convex curve an hyperboloid, is yet to be seen. I am working at this, and hope to have something from trial; but, in view of the possibilities of this form of telescope, I hope that some competent person will take up the investigation of the theoretical conditions involved, so that the best can be made of this form of reflecting telescope.

Preliminary Note on the Determination of Terrestrial Longitudes by Photography. By Captain E. H. Hills, R.E.

The question of the practicability of some method for the determination of longitudes by means of photographs of the moon and stars is one that has engaged the attention of several experimenters.

It is one of great importance for the explorer and surveyor, the inaccuracy of the methods at present available being so great that they are practically never employed in the field.